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Midwest Research Institute

Precooked Dehydrated Meals
for Air Force Conditions

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QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES
Research and Engineering Command
Quartermaster Corps, U.S. Army
Chicago, Illinois

AD Accession No. Midwest Research Inst. Kansas City, Mo. Precooked Dehydrated Meals for Air Force Conditions Report No. 1 (Final), Contract DAL9-129-qm-1645 A set of meals for personnel on medium flight has been developed. These meals consist of compatible, precooked, dehydrated, readily rehydrated food items. They are packaged, along with necessary water to prepare them, in a specially developed container in which the food can be prepared and from which it can be eaten. The meals can be warmed to serving temperature by a heating device developed for the purpose.	UNCLASSIFIED 1. Precooked Dehydrated Meals for Air Force Conditions 2. Contract DAL9-129-qm-1645	AD Accession No. Midwest Research Inst. Kansas City, Mo. Precooked Dehydrated Meals for Air Force Conditions Report No. 1 (Final), Contract DAL9-129-qm-1645 A set of meals for personnel on medium flight has been developed. These meals consist of compatible, precooked, dehydrated, readily rehydrated food items. They are packaged, along with necessary water to prepare them, in a specially developed container in which the food can be prepared and from which it can be eaten. The meals can be warmed to serving temperature by a heating device developed for the purpose.	UNCLASSIFIED 1. Precooked Dehydrated Meals for Air Force Conditions 2. Contract DAL9-129-qm-1645
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CONTRACT RESEARCH PROJECT REPORT

QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES, CHICAGO
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Conditions

PREFACE

Work on Project No. 2422-C, "Precooked Dehydrated Meals for Air Force Conditions," was performed under the supervision of Dr. L. H. Goodson and Mr. Martin N. Schuler, Heads, Biochemistry and Industrial Chemistry Sections. Mr. Carl Perkins, Head, Mechanical Engineering Section was responsible for tray design and fabrication, and Mr. Howard Christie developed packaging techniques. Mr. O. B. Gerrish served as project leader. Dr. Frank Wells, Mr. Roger Schreeder, Mr. Earl White, Mr. C. R. Moninger, Mr. Don Gaddis and Mr. Dick Coe contributed to the project. Food items were furnished by the Quartermaster Food and Container Institute for the Armed Forces and by Wilson and Company, Inc. Mr. A. S. Henick, Project Officer, rendered valuable assistance throughout the entire program.

Approved for:

MIDWEST RESEARCH INSTITUTE

B. W. Beadle, Director
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9 May 1962

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SUMMARY

A set of meals for personnel on medium-duration flights has been developed. These meals consist of compatible, precooked, dehydrated, readily rehydratable food items. They are packaged, along with the necessary water to prepare them, in a specially developed lightweight container in which the food can be prepared and from which it can be eaten. The meals can be warmed to serving temperature by a distinctive heating device developed for the purpose.

Two hundred and seventy complete meals (30 each of nine different meals) along with a heating device and directions for preparing the meals were delivered to the sponsor. Each meal consisted of at least one meat entree (and/or equivalent) and at least one vegetable and one dessert. All the meals were unitized on a compartmented tray. The majority of the individual foods were precooked, freeze-dried, Quartermaster items. In addition, some specially developed items along with prepared cereals were included. Notorious flatus-producing foods were not used.

The packaging and serving tray was fabricated from 0.012 in., dead soft aluminum using hydroforming techniques. Outer edges, as well as the tops of partitions between compartments, were essentially wrinkle-free. This type of tray design permitted hermetic seals between the foil cover, each compartment and the outside edges. Hot polyvinyl acetate was used as an adhesive to seal the foil top to the tray.

Measured quantities of water necessary to rehydrate the individual menu items were sealed in pouches and placed in each compartment of the tray. Heat-sealed Mylar-foil-polyvinyl acetate laminated pouches were used for water storage.

The majority of the menu items, when prepared according to directions, were palatable within 10 to 15 min. However, two items, green beans and apricots, were not freeze-dehydrated, and consequently exhibited relatively poor rehydration characteristics.

Palatability and stability of the menu items in this system are satisfactory for short-term usage. However, many refinements are needed before such a system can become operational. Packaging freeze-dehydrated menu items plus a pouch containing rehydration water in the same compartment or container is expensive in terms of space. This condition exists

because the dehydrated item does not shrink on drying and thus has the same space requirement as the normally rehydrated food.

Additional work is also called for on container design. The rounded bottoms of each compartment in the tray are convenient from the standpoint of rehydration and serving the food. However, much space on the under side of the trays between the compartments is wasted when the trays are stacked. Completed units supplying food plus rehydration water for one man for three days weigh approximately 11-3/4 lb. and occupy 0.9 cu. ft.

Requirements for hydroforming were best met by the use of dead soft aluminum; however, this material forms a tray which is not sufficiently rigid to stand the rigors of rough handling. Future trays of this type should be designed with sufficient rigidity to minimize the danger of seal failure occasioned by bending the tray.

The need for bacteriological study and adoption of standards for freeze-dehydrated foods is critical. The freezing and drying processes are such that the protection given against the denaturization of native food proteins should be expected to apply to the contaminating bacterial cells as well. This could well result in high survival rates of undesirable microorganisms.

I. INTRODUCTION

Good food will improve an astronaut's chances of surviving and functioning efficiently during a journey of even a few days. It will become even more important as the length of the journey increases. The food is "good" if the astronaut enjoys eating it and if it supplies his nutritional requirements.

Taylor, Finkelstein, and Hays^{1/} have pointed out that a variety of highly acceptable foods improves morale. The Air Force has therefore continued to sponsor a series of programs to improve space-feeding systems.

This report discusses a feeding system designed for space flights of medium duration (a few days to a few weeks). The foods studied were for the most part freeze-dehydrated, precooked, and rapidly rehydratable. Many of these items will soon become commercially available.

Dehydration preserves food items without refrigeration. Freeze-dried foods make possible the maintenance of high quality. However, space-flight meals have additional requirements, and although the weight of freeze-dehydrated foods is always reduced, the volume is not reduced proportionately. When possible, acceptable organoleptic properties were retained.

The best approach, therefore, was to package freeze-dehydrated, precooked foods in a container which could be utilized for both the preparation and the serving of meals.

The investigation has been divided into two phases. Phase One evaluated food-to-container ratios, the selection of menus, the development of a packaging and serving tray, as well as the designing and assembly of water pouches and a tray-heating device.

Phase Two studied the assembly of meals and the storage-testing of the final packaged units.

^{1/} Taylor, Albert A., Finkelstein, Beatrice, Hayes, Robert E., ARDC Technical Report No. 60-8, July 1960.

The research program has four parts:

1. Menu selection and menu design;
2. Packaging, heating, and rehydration;
3. Storage and stability tests; and
4. The production of 270 meals (30 units each containing nine meals).

II. DISCUSSION

This research program has demonstrated that a feeding system which consists of precooked, dehydrated, compatible, and readily rehydratable food items is feasible for Air Force conditions.

What is new is the packaging of these items along with the necessary water for preparation in a specially developed lightweight container. The food can be prepared in this tray, and eaten directly from it. A heating device developed for the tray heats the meals to serving temperature.

Freeze-drying preserves the flavor of the foods.

Hot meals can be prepared, under this system, within 10 to 15 min.

These food items maintain a relatively high quality for 60 days at 90°F; however, some meat items start to deteriorate at the end of this period.

Fabrication of a suitable storage and serving tray is difficult. The upper edges of the tray, i.e., the sealing surfaces, must be wrinkle-free if hermetic seals are to be achieved. (The familiar "TV" dinner trays do not meet this requirement.) Special hydroforming techniques had to be developed, and, if this tray is to become a production item, more engineering studies will be necessary. Future trays should have a greater rigidity than the experimental trays.

Low-bulk density of freeze-dehydrated foods, taken together with the space required for the packaging of the necessary water for rehydration, requires that additional space be allowed for in the trays.

III. PROCEDURES AND RESULTS

Procurement of precooked, freeze-dehydrated menu items for evaluation to determine applicability for this project was difficult because of limited commercial production. However, the Quartermaster Food and Container Institute provided many of the items and others were experimentally produced by Wilson and Company.

Three items exhibiting promise for future programs of this type were experimentally evaluated, but were unavailable for packaging in the prototype meals delivered to the sponsor. These items were: (1) white sauce, (2) mushroom sauce, and (3) ground beef with white sauce. The white sauce increases the appeal of the peas, mushroom sauce is excellent with green beans and also with flake steak, while the ground beef with white sauce is a good breakfast item. Directions for preparation follow:

White Sauce

1 qt. scalded whole milk	Melt the shortening, add the flour and
100 g. shortening	blend until smooth. Add salt, pepper
55.5 g. white flour	and onion powder. Then add scalded
13 g. salt	milk gradually with constant stirring
0.2 g. white pepper	while heating over a low flame. Boil
0.2 g. onion powder	5 min. Cool. Freeze-dry.

Ground Beef with White Sauce

Add 1 lb. of browned, ground beef to the sauce prior to freeze-drying.

Mushroom Sauce

1 qt. water	Melt the shortening. Add the flour
100 g. shortening	and blend until smooth. Add the BV.
55.5 g. white flour	Add the water gradually with con-
28 g. Wilson's BV	stant stirring while heating over a
350 g. drained, canned	low flame. Boil 3 min. Add mush-
mushrooms	rooms. Bring to boil and boil 5 min.
	Cool. Freeze-dry.

Canned corn beef hash cut into slices 1/2 in. thick and freeze-dried was evaluated as a breakfast item. Initial acceptance was very good; however, the material became unpalatable after three weeks' storage at 90°F.

Canned, small, whole sweet potatoes were freeze-dried and evaluated. Palatability was good, but on occasion a portion of the center of the individual potatoes failed to rehydrate.

Three tentative daily menus were originally submitted. Pertinent preliminary information covering rehydration characteristics, nutritional data, and water-to-food volume relations for each of these three menus is presented in Tables I, II and III. With exception of substitution of more refined cereals and some other unavailable menu items, these tentative menus are essentially the same as the final menus presented in Tables IV, V and VI.

In the interest of simplicity for packaging and serving, the contractor designed each of the nine meals in such a fashion that each was packaged in a compartmented tray or other unitized meal type array which permitted rehydration and serving from the package. This occasionally led to some wasted space in the individual compartments because irregular shapes of the menu items plus differences in density of many of them led to wide variations in the food-volume requirements of the precooked, freeze-dried product.

The size of individual servings in each of the tentative menus accompanying this report is based, when possible, on information pertaining to the size of one-man servings of many precooked, dehydrated food items furnished by the Quartermaster Food and Container Institute. Nutritional data calculated from U. S. Department of Agriculture Handbook No. 8^{2/} indicate that none of the daily menus submitted reached the 2,000 to 2,200 calorie requirements for this project. Minimum daily protein requirements, however, as recommended by the National Research Council^{3/} are exceeded. Since each tentative menu submitted contains only the minimum required items, it is possible to raise the caloric value to the desired level by either increasing the portion or size or including additional or more calorie dense items in the menu.

^{2/} Composition of Foods, U. S. Department of Agriculture, Agriculture Handbook No. 8, Washington, D. C. (1950).

^{3/} Recommended Dietary Allowances, Publication 589, National Academy of Sciences - National Research Council, Washington, D. C. (1958).

TABLE I

TENTATIVE MENU NO. I
(Calories 1,494 - Protein 95 g.)

Item	Grams	Calories	Protein (g.)	Volume Relationships		Rehydration Data 165°F	
				Actual	Required to Package	Water (ml.)	Time (min.)
<u>Breakfast</u>							
Scrambled Eggs	28	170	11	125	190	84	2
Corn Flakes, Milk, Sugar	45	172	5	81	90	80	1
Peaches	17	58	1	110	225	62	3
<u>Dinner</u>							
Flake Steak	70	390	45	224	375	140	10
Sweet Potatoes	35	134	2	134	225	122	5
Fruit Cocktail	17	60	0.5	170	225	68	5
<u>Supper</u>							
Pot Roast and Gravy	70	325	27	184	250	140	10
Diced Potatoes	35	128	3	190	250	210	5
Applesauce	17	57	0.5	31	35	83	1

TABLE II

TENTATIVE MENU NO. II
(Calories 1,664 - Protein 95 g.)

Item	Grams	Calories	Protein (g.)	Volume Relationships		Rehydration Data 165°F	
				Actual	Required to Package	Water (ml.)	Time (min.)
<u>Breakfast</u>							
Prefried Bacon	56	382	14	61	100	-	-
Sugar-coated Corn Flakes, Milk, Sugar	45	167	14	120	100	45	-
Fruit Compote	17	59	0.5	32	75	68	20
<u>Dinner</u>							
Swiss Steak (Gravy)	70	318	36	137	250	210	10
Mashed Potatoes	35	128	0.5	47	35	128	1
Apricots	17	58	1	180	300	85	5
<u>Supper</u>							
Beef Loaf	65	375	28	162	250	98	20
Lima Beans	35	118	3	147	225	123	10
Peaches	17	59	1	110	225	62	3

TABLE III

TENTATIVE MENU NO. III
(Calories 1,606 - Protein 101 g.)

Item	Grams	Calories	Protein (g.)	Volume Relationships		Rehydration Data 165°F	
				Actual	Required to Package	Water (ml.)	Time (min.)
<u>Breakfast</u>							
Beef and Potato Hash	71	403	31	220	225	142	5
Wheaties, Milk, Sugar	45	174	15	90	100	90	10
Apricots	17	58	1	180	300	85	5
<u>Dinner</u>							
Chicken and Rice	70	303	21	350	400	245	10
Peas	35	131	9	189	200	140	5
Pineapple	17	59	0.5	60	150	51	5
<u>Supper</u>							
Spaghetti and Meat Sauce	84	391	21	244	350	210	20
Green Beans	9.5	27	2	127	200	95	5
Fruit Cocktail	17	60	0.5	170	225	68	5

TABLE IV

NUTRITIONAL DATA(Size of Portions, Caloric Value and Grams of
Protein for Three Breakfast Menus)

	<u>Serving</u> <u>(g.)</u>	<u>Calories</u>	<u>Protein</u> <u>(g.)</u>
I. Scrambled Eggs	28	170	11
Corn Flakes, Sugar, Milk	45	172	5
Peaches	<u>17</u>	<u>58</u>	<u>1</u>
Total	90	400	17
II. Prefried Bacon	56	382	14
Sugar-coated Corn Flakes,			
Milk	45	172	
Fruit Cocktail	<u>17</u>	<u>59</u>	<u>0.5</u>
Total	118	613	
III. Beef and Potato Hash	71	403	31
Bran Flakes, Sugar, Milk	45	171	
Apricots	<u>17</u>	<u>58</u>	<u>1</u>
Total	133	632	

TABLE V

NUTRITIONAL DATA(Size of Portions, Caloric Value and Grams of
Protein for Three Dinner Menus)

		<u>Servings</u> <u>(g.)</u>	<u>Calories</u>	<u>Protein</u> <u>(g.)</u>
I.	Flake Steak	70	390	45
	Sweet Potatoes	35	134	2
	Fruit Cocktail	<u>17</u>	<u>60</u>	<u>0.5</u>
	Total	122	584	47.5
II.	Swiss Steak (Gravy)	70	318	36
	Mashed Potatoes	35	128	0.5
	Apricots	<u>17</u>	<u>58</u>	<u>1</u>
	Total	122	504	37.5
III.	Chicken and Rice	70	303	21
	Peas	35	131	9
	Pineapple	<u>17</u>	<u>59</u>	<u>0.5</u>
	Total	122	493	30.5

TABLE VI

NUTRITIONAL DATA

(Size of Portions, Caloric Value and Grams of Protein for Three Supper Menus)

	<u>Servings</u> <u>(g.)</u>	<u>Calories</u>	<u>Protein</u> <u>(g.)</u>
I. Pot Roast (Gravy)	70	325	27
Diced Potatoes	35	128	3
Applesauce	<u>17</u>	<u>57</u>	<u>0.5</u>
Total	122	510	30.5
II. Beef Loaf	65	375	28
Lima Beans	35	117	7
Peaches	<u>17</u>	<u>59</u>	<u>1</u>
Total	117	551	36
III. Spaghetti and Meat Sauce	84.0	391	21.0
Green Beans	9.5	27	2.0
Fruit Cocktail	<u>17.0</u>	<u>60</u>	<u>0.5</u>
Total	110.5	478	23.5

Furthermore, it is expected that the meals will be supplemented by bread, spread, and beverages currently available as regular Quarter-master items.

A. Water Pouches

The integrity of the seal of the water pouches was a critical factor in the final packaging operation. These seals were required to hold during handling, packaging and throughout the storage life of the meal. Any leaking unit found before the final packaging operation was not a cause for concern; however, should a potential leaker be placed in a tray, the meal could ultimately be lost. As the sealing press comes down to join the cover and the tray, some pressure is transferred to the food components. If the seals on a water packet were weak, any small pressure could cause rupture.

By an examination of the rejected pouches, it was found that the greatest difficulty was encountered in these pouches containing the largest amounts of water. The reason for the weaker seals in these units was felt to be related to a lessening of the area to which the seal could be applied--without a cooling effect from the water. With high water volumes, the liquid in the pouch came close enough to the lips on the sealing machine to keep the temperature below the 350°F found necessary to insure seals of adequate strength. Should water packs be required in the future, an additional allowance in pouch size will have to be made for the larger volume packets.

Two types of sealing (for water packets) were investigated. One was by use of ultrasonics and the other by the more conventional heat and pressure seal. Five mil aluminum stock was used for the ultrasonically-sealed units.

Two laminate materials were used for the heat-sealed packages: Mylar-foil-polyethylene laminate and Mylar-foil-polyvinyl acetate. For the heat-sealed pouches, a temperature of 350°F was used and applied for 5 sec. at a pressure of 60 psi.

Ultrasonic sealing was found to be unsatisfactory. As the data in Table X, p. 21, show, several of the bags were ruptured. The

rupturing came from an accumulation of gas within the sealed pouch. It is thought that this gas formed as a result of electrolytic processes. The full reason and mechanism were not studied during this investigation.

Mylar-foil-polyethylene laminates proved unsatisfactory because the material had a tendency to delaminate within two weeks' storage at 120°F.

Heat-sealed Mylar-foil-polyvinyl acetate laminate pouches were found to perform satisfactorily under all test conditions employed. The stability of the seals may be ascertained from a study of the data presented in Table XI, p. 22.

Because of the satisfactory test performance of these laminate pouches, all water packs used in the finished meals were made with this material. A sealing temperature of 350°F applied for 1 sec. at 60 psi pressure was used to make all seals in forming and closing the packets.

B. Rehydration Characteristics

The rehydration of the foods tested during this study was done at a temperature of 165°F. The initial water temperature was 80°F. The temperature of the tray was maintained at 165°F $\pm 2^\circ$ by immersion in a water bath.

As a starting point, water was added at a level near that present in the fresh food. Levels both above and below this base were then tested. A satisfactory level was considered to be the amount which would allow for rehydration of the food without soggyiness or excessive free liquid remaining, while resulting in a rehydrated product with an appearance and "mouth feel" close to the fresh food. Generally, the level of water necessary to achieve this fell below the quantity normally present in the fresh or the fresh-cooked product.

The rate of heating was determined by placing a thermometer at the center of the food mass and recording the temperature change at regular time intervals. When a satisfactory water level was established, the quantity of material to be used in the finished meal was weighed into a tray and the calculated amount of water was added to it. If, after checking duplicate samples, the rehydration characteristics were still satisfactory, a sufficient water level was considered to have been established for that particular food.

Data presented in Table VIII, p. 19, and Table IX, p. 20, show the water levels found satisfactory for most of the food items and the temperature obtained after 10-min. heating.

Early in this investigation, the observation was made that rehydration characteristics of dehydrated foods were extremely variable. The variation exists even among foods of a given class which had been dried as different lots. Even though the physical conditions of drying were considered equal (time-temperature relationships), the resultant products were not always equal. Undoubtedly, some of the variation lies in the differences in the raw materials--that is, varietal differences, geographical and seasonal differences, and age of raw material before drying as well as factors more subtle. When one considers the possible effects of drying equipment and technique, it is indeed a difficult task to assign rehydration characteristics to a product within close limits.

The authors would point out the need for research in this area (as well as most other areas related to freeze-dehydration) pointing to some of the aforementioned problems as indications of that need. Freeze-dried foods of uniform quality and functional characteristics can be obtained only when they are consistently produced from raw materials of uniform quality. It may be expected that freeze-dehydrated peas produced from thick-skinned peas will not be the same as a product made from peas possessing a thinner skin. This variation became evident as the rehydration characteristics of one lot of green beans was studied. A subjective test for the degree of plumping was made with the following results:

Full plumped	17 per cent
Half plumped	39 per cent
Less-than-half plumped	44 per cent

Presumably all the beans were prehandled in the same manner and were subjected to similar freezing and drying conditions. It must be assumed that the differences, if not attributed to the processing, must be variations inherent in the raw materials. It must also be emphasized that the beans in this test were not freeze-dehydrated, but rather a vacuum-dried product. The emphasis we wish to make, however, is that variations in the finished products are influenced by the quality of the raw materials and that this variation will be carried over to the finished products regardless of the method of drying used.

When rehydration time of a dried product is influenced by temperature, the type food under study plays a greater part. In other words, the time required to bring the temperature of beef loaf to 165°F will be quite different from the time required to bring the temperature of lima beans to the same level. In addition to the factor of temperature, consideration must necessarily be given to the amount of water used for rehydration of a given item. It may be observed that a slight excess of water for rehydrating peaches would not be as objectionable as an excess for peas or lima beans--syrup in fruit is desirable. Further, the excesses which can be allowed with fruits and vegetables cannot be allowed with a product such as beef loaf where free water is objectionable. Where it is possible to use an excess of water, allowing the excess as syrup or soup, rehydration times can be shortened. Where it is not possible to use excess fluid, rehydration time is lengthened. With the beef loaf, when water just sufficient for rehydration was added to the dried material, it was rapidly absorbed. If the loaf was broken as soon as absorption occurred, it was found that there were alternating areas of wet and dry throughout the material. An additional time lapse was then necessary in order to accomplish uniform wetting of the loaf. If, in addition to uniform wetting, the requirement for uniform heating was applied, a further time allowance had to be made.

Other difficulties in rehydration were found in products composed of more than one food class and which possessed different rehydration rates. One such item was spaghetti and meat sauce. In such a product, it was necessary to mix and remix the material at frequent intervals in order to achieve uniform hydration. The most easily hydrated item in such a mixture absorbs and holds water in excess of that necessary for rehydration, and the more slowly hydrating component then rehydrates even more slowly since the water must be obtained through equilibration with the rapidly hydrated item.

Beef and potato hash was another of the items which was variable in its rehydration characteristics. It also shows the extremely slow heating characteristics of such products. The rate of rehydration and the amount of water necessary to rehydrate this product will vary depending upon the ratio of potato to meat within a sample as well as the size of the potato particle. The water is so rapidly absorbed by the potato that the heating of the mass is an extremely slow process. Even with a 15-min. rehydration time, the hash was not uniformly heated to 140°F, nor was hydration completely uniform. Over-hydration had to be carefully prevented since the attendant "soup" made the product unsatisfactory. Again we would emphasize the need for studies which

would define some of the factors necessary to give the finest rehydrated products possible. The factors and conditions of drying have been more adequately studied. Perhaps it is now time for an investigation of the factors inherent within a food which allow or prevent the production of high quality end products. The need for bacteriological study is critical. There is, throughout the literature, sufficient evidence to show that the effect of a physical stress, such as freezing, is sufficient to cause a change in the growth rate and pattern of the surviving bacteria. Often the change is such that the survivors grow at rates in excess of those considered to be characteristic of their respective groups. Such a condition (with freeze-dehydrated foods) should cause us to examine carefully the allowable minimum total population (when standards are adapted) for these foods. If the freezing and drying processes are such that protection is given against the denaturation of native food proteins, a similar protective effect can be expected to apply to the contaminating bacterial cells. The maintenance of viability of lyophilized bacterial cultures is an argument in favor of the development of a new standard and code for freeze-dehydrated foods. Further, the long lag phase of growth often evidenced in cells debilitated by physical stress, such as dehydration or freezing, may not be characteristic for cells persisting in freeze-dehydrated foods. The absence of the long lag phase in bacteria dried by lyophilization, compared to those bacteria dried by other methods, is a primary reason for the production of freeze-dried "starter" cultures for fermented dairy products. If it can be demonstrated that the bacteria persisting in and on freeze-dehydrated foods do have altered growth patterns, growth rates, shorter lag time following restoration of growth conditions, and if it can be shown that the freeze-dehydration process results in greater survival of the contaminants, an evaluation of the allowable numbers and types of bacteria permitted on foods prepared by the freeze-dehydration process would be in order.

C. Nutritional Data

All meals were selected to give assemblies which would yield a package of as uniform size as possible and which would, at the same time, give a minimum weight for cube and the most optimum food-to-package ratio. Because variety of food types was also essential, it was not possible to select many different foods and yet maintain a given food-to-package ratio while achieving a uniform caloric value. Nutritional data are presented in Tables I through VII.

TABLE VII

NUTRITIONAL DATA
(Caloric Values of Meals Singly and As A Daily Ration)

<u>Breakfast</u>	<u>Dinner</u>	<u>Supper</u>	<u>Total</u>
I (400)	I (584)	I (510)	1,494
II (613)	II (504)	II (551)	1,668
III (632)	III (493)	III (478)	1,603

Limitations of size and weight necessitated the reduction of caloric value from an original estimate of 2,000-2,200 per man per day to levels ranging from a low of 1,371 to a high of 1,767. The caloric level would depend upon the assortment of meals chosen for any given day. As shown in Table VII, should all No. I menus be chosen, the total caloric level would be 1,494 calories per man per day. If No. II menus were chosen, the level would be 1,668, and if No. III menus were chosen, the level would be 1,603.

On the other hand, if random selection was employed, and the lowest energy meals were picked, the caloric value would be 1,371; a random selection of the highest energy meals would result in 1,767 calories per man per day.

D. Final Packaging

The stability (or instability) of dehydrated meat and meat products is such that packaging in an atmosphere containing less than 1 per cent oxygen was considered necessary. In order to accomplish this, a dry packaging chamber was made in which the trays could be loaded and sealed under nitrogen gas.

Essentially, loading of the trays and sealing was of the following order:

1. The food components for a meal, along with the trays and tops, were placed in the dry box and the box sealed.
2. The box was flushed with nitrogen gas until an analysis of the gases within the box showed oxygen to constitute less than 1 per cent of the mixture.

TABLE VIII

SOME REHYDRATION CHARACTERISTICS OF VACUUM
AND FREEZE-DEHYDRATED FOOD ITEMS

<u>Item</u>	<u>Dry Weight (g.)</u>	<u>Water (g.)</u>	<u>% H₂O</u>	<u>Minimum Hydration Time</u>	<u>Drying Process</u>	<u>Supplier</u>
Green Beans	9.5	43	82	20	Vacuum	QMFCI
Peas	35.0	117	77	10	Freeze-dehyd.	QMFCI
Potatoes	35.0	115	77	20	Vacuum	QMFCI
Lima Beans	35.0	82	70	10	Freeze-dehyd.	QMFCI
Fruit Cock- tail	17.0	51	75	10	Freeze-dehyd.	QMFCI
Peaches	17.0	67	67	10	Freeze-dehyd.	QMFCI
Apricots	17.0	85	82			
Pineapple	17.0	51	75	10	Freeze-dehyd.	QMFCI
Beef Loaf	65.0	98	60	20	Freeze-dehyd.	Wilson
Flake Steak	70.0	85	55	15	Freeze-dehyd.	Wilson
Chicken and Rice	70.0	200	74	10	Freeze-dehyd.	Wilson
R. Beef and Gravy	70.0	180	72	15	Freeze-dehyd.	Wilson
Spaghetti and Meat Sauce	84.0	210	71	15	Freeze-dehyd.	Wilson
Beef and Po- tato Hash	71.0	210	76	20	Freeze-dehyd.	Wilson
Sweet Potatoes	35.0	74	68	10	Vacuum	QMFCI

TABLE IX

TEMPERATURE OF FOODS AFTER 10 MIN. REHYDRATION
WITH A TRAY TEMPERATURE OF 165°F

<u>Food Item</u>	<u>Initial Temperature of Water (°F)</u>	<u>Temperature of Food (10 min.)</u>	<u>Temperature of Tray (°F)</u>
Lima Beans	80	145	165
Peaches	80	152	165
Pineapple	80	150	165
Beef Loaf	80	138	165
Flake Steak	80	140	165
Chicken and Rice	80	140	165
R. Beef and Gravy	80	138	165
Spaghetti and Meat Sauce	80	142	165
Potatoes	80	151	165

TABLE X

CHANGES IN POUCH WEIGHTS OF 5 MIL ALUMINUM
WATER PACKETS SEALED ULTRASONICALLY

Initial Package Weight (g.)	Days Storage (Room Temperature)						
	1	2	3	4	5	6	7
159.96	157.90	157.86	157.83	157.77	157.76	157.76	157.76
159.42	153.03	149.08	Leaking Bag	- - - -	- - - -	- - - -	- - - -
166.20	166.20	166.20	166.20	166.20	166.20	166.20	166.20
164.26	164.26	164.26	164.26	164.26	164.26	164.26	164.26
166.96	166.95	166.95	166.95	166.95	166.95	166.95	166.95
166.25	166.07	165.98	164.24	Leaking Bag	- - - -	- - - -	- - - -
167.01	167.01	167.01	167.01	167.01	167.01	167.01	167.01
120°F Storage							
	1 Wk.	2 Wk.	3 Wk.				
166.95	166.41	162.24	160.33*				
167.01	166.69	166.67	136.17*				
157.76	145.17	145.06	144.09*				

* Ruptured Bags.

TABLE XI

CHANGES IN POUCH WEIGHTS OF LAMINATED WATER PACKETS SEALED BY
HEAT AND PRESSURE (POLYETHYLENE TEREPHTHALATE,
FOIL ALUMINUM AND POLYVINYL ACETATE POUCHES)

Initial Package Weight (g.)	Days Storage (Room Temperature)		
	<u>1 Wk.</u>	<u>2 Wk.</u>	<u>3 Wk.</u>
152.72	152.72	152.71	152.72
150.15	150.14	150.16	150.15
149.93	149.93	149.93	149.93
151.47	151.44	151.47	151.46
125.88	125.88	125.87	125.87
125.56	125.65	125.56	125.56
125.70	125.70	127.70	125.70
125.91	125.91	125.91	125.91
	<u>120°F Storage</u>		
125.71	125.68	125.68	125.67
125.95	125.90	125.89	125.90

3. When the proper packaging atmosphere had been established, the food components were weighed into the trays, the water pouches put in the compartments, and the lid placed on and heat-sealed.

4. When all the meals of a menu were sealed, the nitrogen in the box was released, the box opened, and the trays removed.

5. The trays were then inspected and those possessing satisfactory seals were trimmed and labeled.

E. Tray Design and Fabrication

The production of a packaging and serving tray to meet the requirements of this study posed a difficult problem. Original plans called for the food items to be packaged under a partial vacuum. Therefore, it was necessary that the tray be light and yet strong enough to withstand a partial vacuum. In addition, all partitions and outside edges had to be wrinkle-free if adequate hermetic seals were to be achieved. In order to procure a tray with wrinkle-free partitions and edges, strength had to be sacrificed. Consequently, the final trays were produced from soft aluminum which would not stand vacuum packing so that the prototype meals were gas-packed.

An early concept of the proposed serving tray is shown in Appendix I. A commercial aluminum fabricator (EKCO-Alcoa) was contacted in regard to the production of the trays. On first appraisal, the company felt they could supply the item by forming it on a mechanical press. Consultations between the company and project personnel resulted in a modified concept of the tray which was finally adopted. A drawing of the modified container is shown in Appendix II. After many weeks, EKCO-Alcoa became doubtful about their ability to produce a wrinkle-free tray on equipment available in their facility. Using mechanical presses, even three separate draws failed to produce a satisfactory product. Other commercial firms declined to work on the project because of limited funds available and limited demand for the finished tray. It, therefore, became necessary to shop fabricate the trays.

Studies by Midwest Research Institute engineers indicated that hydroforming techniques offered the most effective and practical approach to the problem. Many aluminum forming operations utilizing

hydraulic and mechanical presses require both male and female dies in order to impart the desired form to the material being worked. Hydroforming techniques used to produce the trays in this study required only a female die. In practice, the aluminum blank was clamped between a sealing fixture and a female die in an arbor press. Water pressure was applied to one side of the blank through the sealing fixture (Appendix III). Hydraulic pressure then forced the aluminum into the cavities in the die (Appendix IV), thus forming the compartments in the tray. Trays formed in this fashion were essentially wrinkle-free. When wrinkling did occur, it was of such small magnitude that it could be easily ironed out prior to sealing.

Two types of aluminum were evaluated for hydroforming the trays. Type 3003-0 was investigated first. It contains 1.2 per cent manganese and 98.8 aluminum. This material was investigated because its characteristics best suited it for both hydroforming and ultimate vacuum packing. This type material would not form a satisfactory tray because of a tendency to rupture while the cavities were being formed. Type 1100-0 was then evaluated and used because usable trays could be formed from it. A review of hydroforming results is presented in Table XII.

Trays, then, were fabricated from 0.012 in. dead soft aluminum. To make a unit, a blank 12-1/2 in. x 13-1/2 in. was clamped in the forming equipment with a 6-8 ton hold-down pressure. Hydraulic pressures of 80 lb. per sq. in. forced the aluminum into the die to form the tray. Approximately 1 min. was required for the forming process. Johnson's "700 Wax-Draw" wax emulsion was used to lubricate the dies.

The covers were cut from 5 mil stock aluminum. Using a pattern, adhesive (polyvinyl acetate in acetone) was applied to all outer edges and to the points where the cover would contact the partitions in the tray. The application of the adhesive followed etching by phosphoric acid and washing. Adhesive was also spread on the outer edges of the tray and its partitions. The acetone was evaporated from the covers and trays in an oven. Sealed units were pretested using the sealing material above and, as can be seen from Table XIII, the method gave excellent results. The covers were sealed to the trays at 275°F, applied for 5 sec. at 90 psi. The test method consisted of placing tared, sealed trays, containing calcium chloride, in a desiccator partially filled with water.

TABLE XII

REVIEW OF HYDROFORMING RESULTS

Type	Aluminum		Pressure (lbs/sq in.)		Time	Draws No.	Annealed	Results
	Thickness (in.)	Blank Size (in.)	Hydraulic	Hold Down				
3003-0	0.021	14 x 13-1/2	200	24,000	2 min.	1	No	Ruptured
3003-0	0.021	14 x 13-1/2	200	24,000	2 min.	2	1 hr., 750°F	Ruptured
3003-0	0.021	14 x 13-1/2	250	30,000	3 min.	2	1 hr., 750°F	Ruptured
3003-0	0.012	14 x 13-1/2	200	10,000	2 min.	1	No	Ruptured
3003-0	0.025	14 x 13-1/2	250	10,000	2 min.	1	No	Pulled Edge
3003-0	0.025	14 x 13	80	20,000	2 min.	1	No	Ruptured
3003-0	0.012	14 x 13	80	20,000	1 min.	1	No	Ruptured
3003-0	0.012	13-1/2 x 12-1/2	80	16,000	5 sec.	1	No	Shallow
1100-0	0.012	13-1/2 x 12-1/2	80	16,000	5 sec.	1	No	Irregular
1100-0	0.012	13-1/2 x 12-1/2	80	12,000	10 sec.	1	No	Good
1100-0	0.012	13-1/2 x 12-1/2	80	16,000	10 sec.	1	No	Good

TABLE XIII

WEIGHT INCREASES IN TRAYS CONTAINING CALCIUM CHLORIDE
AND HEAT-SEALED USING POLYVINYL ACETATE
AS THE ADHESIVE IN A MOIST ATMOSPHERE

Initial Tray Wt.	Days of Storage					
	1 Wk.	2 Wk.	3 Wk.	4 Wk.	5 Wk.	6 Wk.
451.5	451.5	451.5	451.5	451.5	451.5	451.5
452.0	452.0	452.0	452.0	452.0	452.0	452.0

The sealing machine was made from an air-actuated press to which an electrically-heated plate was attached. The base for holding the tray was made of the die used in the hydroforming process. To seal a unit, a tray was placed in the die, the cover put in place, and the heated plate forced down on the cover at 90 psi pressure. After 5 sec., the heater plate was raised and the sealed unit removed. Figure 1 shows a tray being taken from the press after sealing. The heated plate is shown in Appendix VI.

F. Heating Device

The heating device (Appendix V) was made of aluminum and was formed in the general shape of the meal tray. The over-all outside dimensions of the tray-grill were 10-1/2 in. x 10-1/2 in. The inside dimensions were made to fit the tray. The tray-grill was enclosed by a side wall 1-3/16 in. in height, and the side wall angles and corners were made specifically to accommodate the tray. A 3-1/2 in. section of one side of the grill was not supplied with a heat source and was separated from the rest of the grill by a 1/4 in. thick Micarta bar. This partition was built in so that a tray could be placed in the heater in such a manner that the "cold-spot" of the grill would hold fruit cocktail, peaches, or other items, which would not be consumed hot. The tray-grill is heated by Chromolox cartridge heater elements with the degree of heating being controlled by a Chromolox type SA thermostat. The amount of heat supplied by the heater is regulated to such a level that the food in the tray may be brought to an eating temperature within the time required for rehydration.

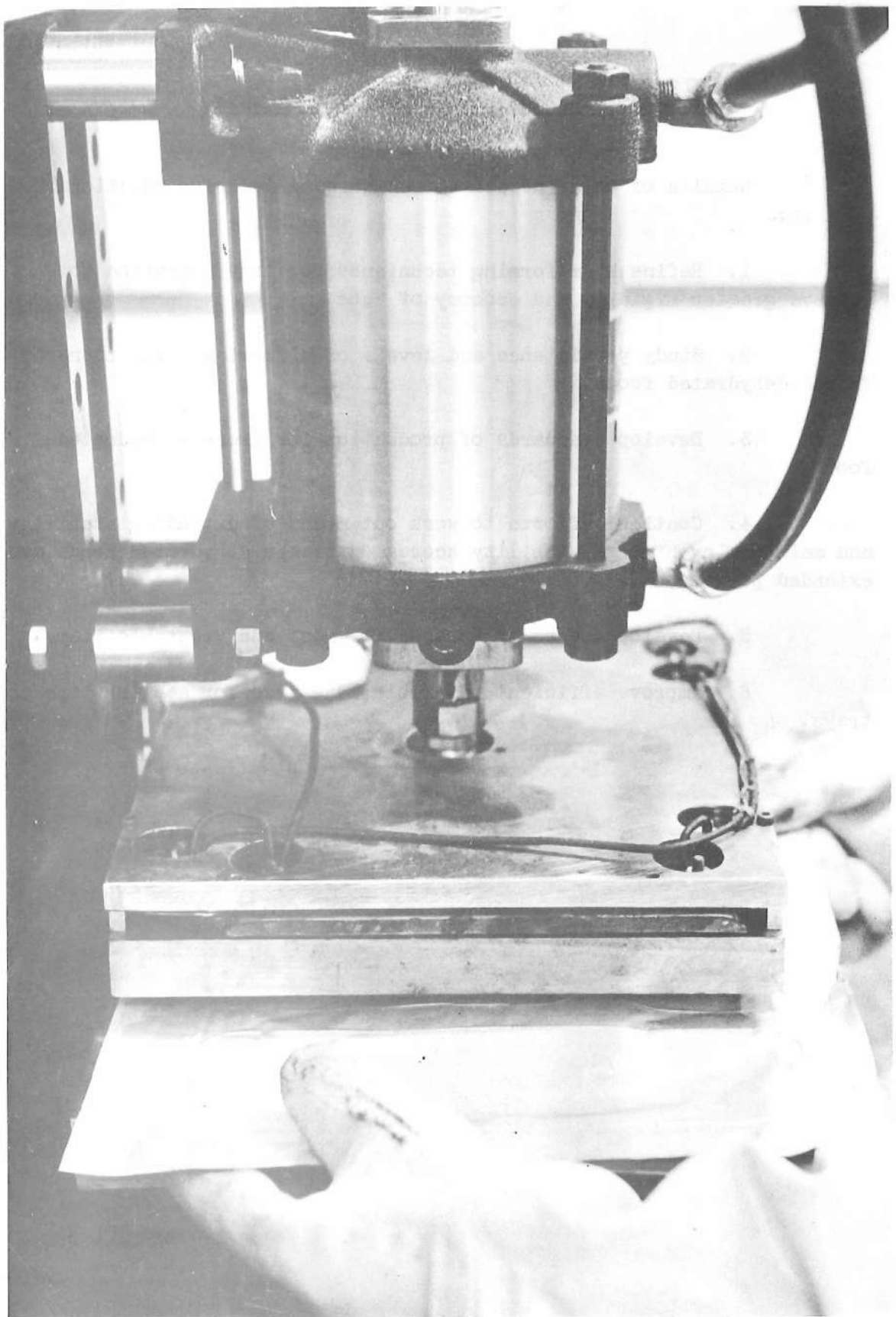
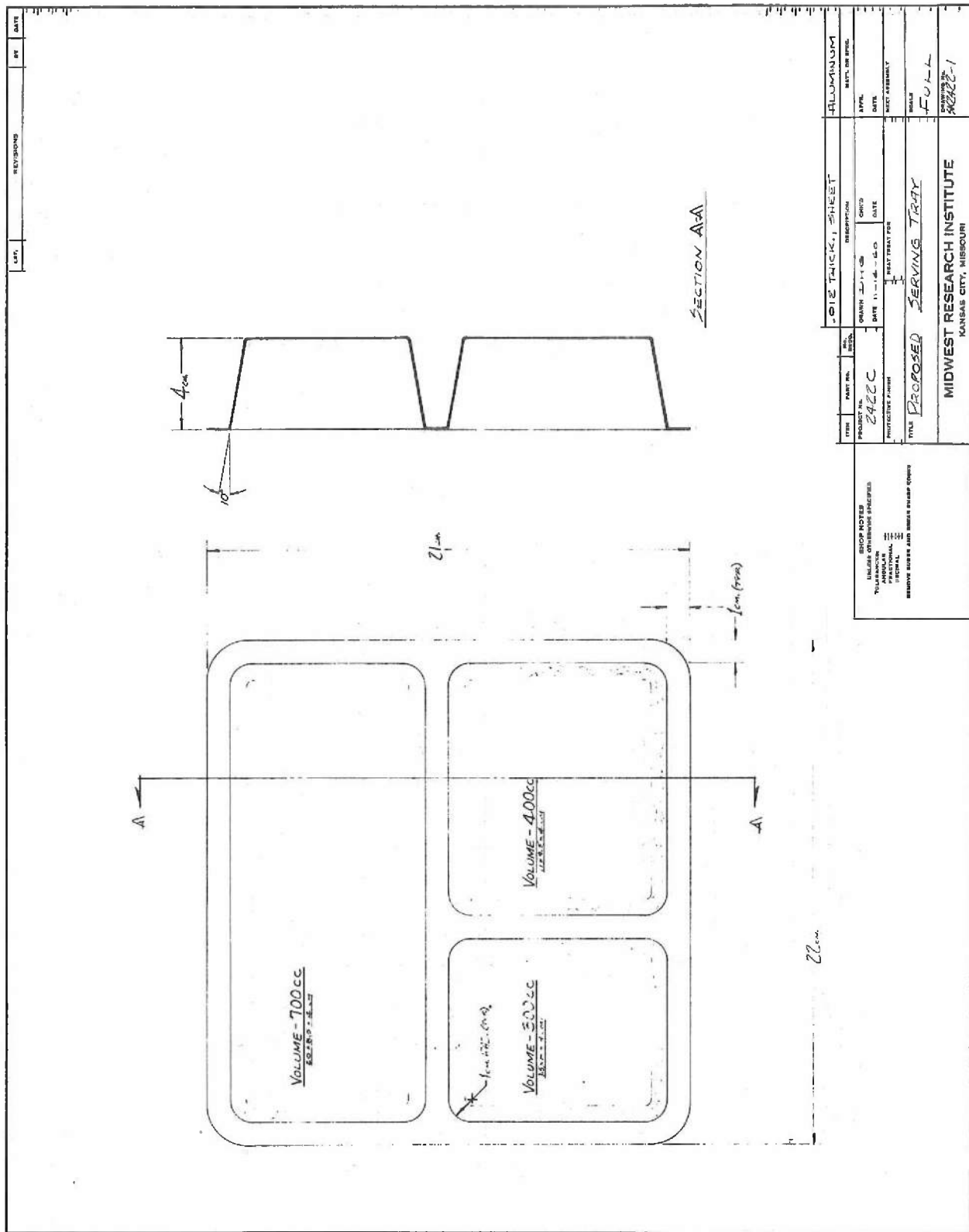


Fig. 1 - Sealed Tray Being Removed From Press

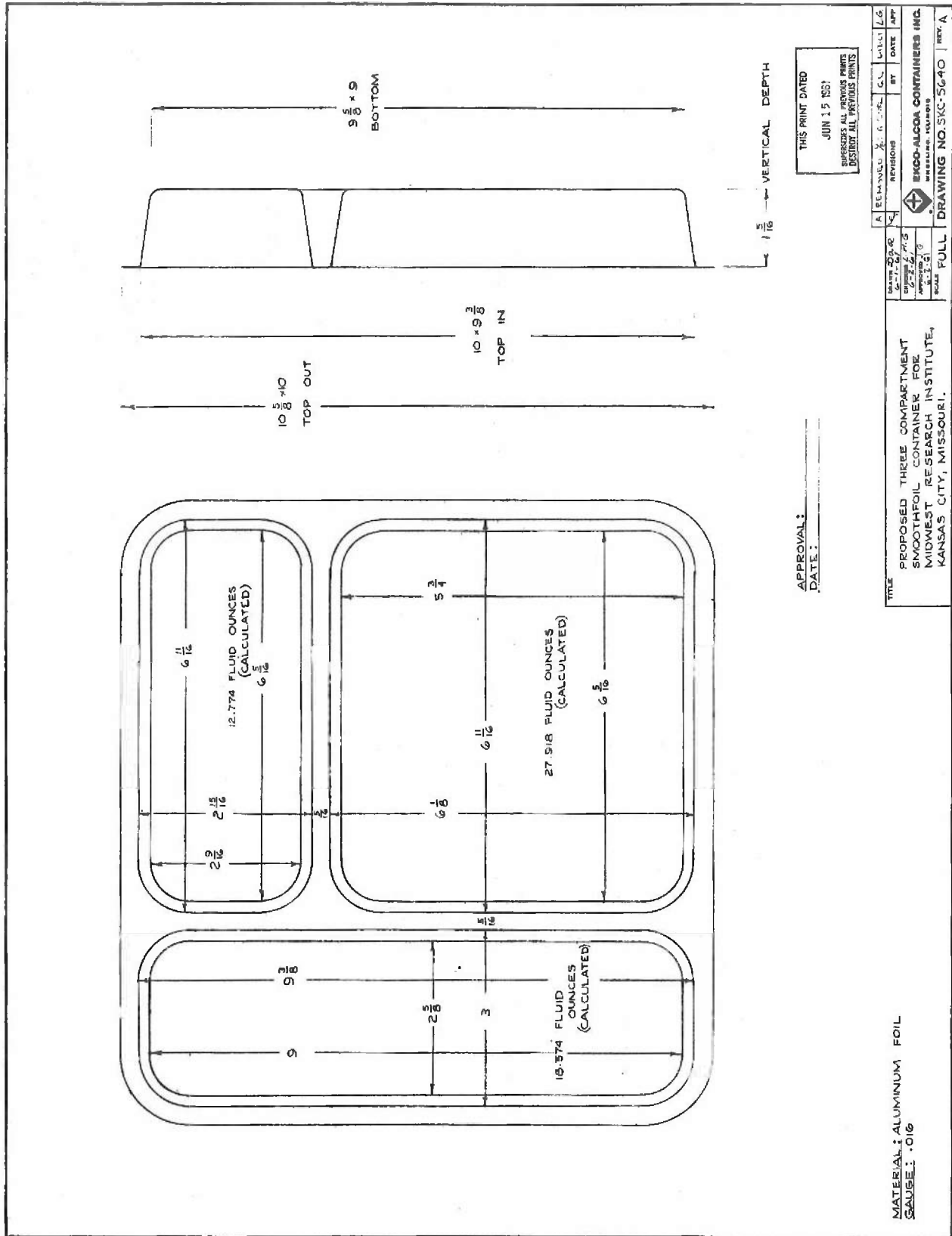
IV. RECOMMENDATIONS FOR FUTURE WORK

Results of this investigation indicate need for additional work to:

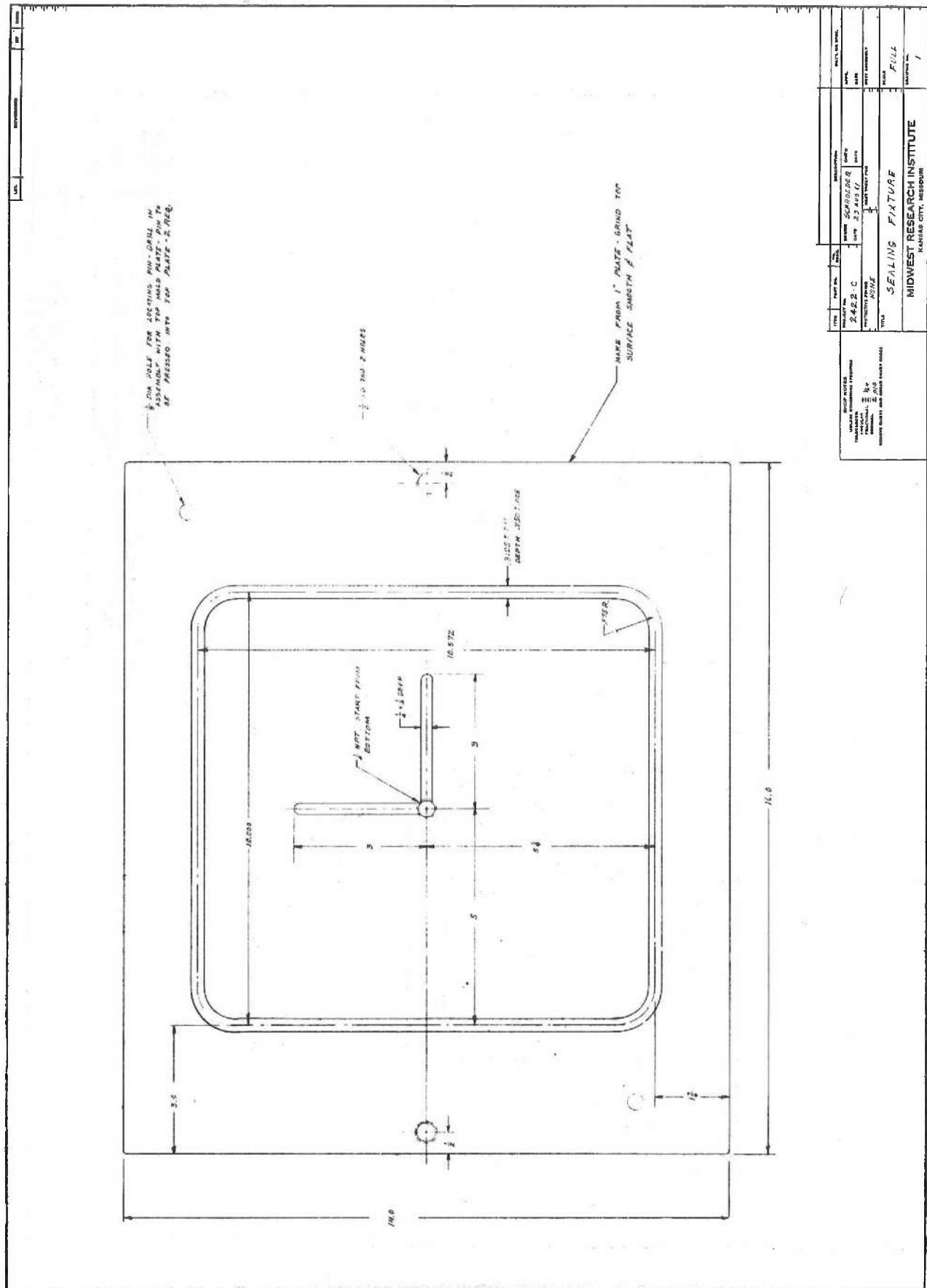
1. Refine hydroforming techniques for tray formation to achieve greater rigidity and economy of cube.
2. Study persistence and levels of microbial populations on freeze-dehydrated foods.
3. Develop standards of production for freeze-dehydrated foods.
4. Continue efforts to work out means of extending stability and maintaining high palatability scores on freeze-dehydrated foods over extended periods.
5. Develop sauces to be used for meat and vegetable items.
6. Improve efficient, flexible adhesives for sealing tops to trays.



Appendix I - Proposed Packaging and Serving Tray



Appendix II - Modified Packaging and Serving Tray



Appendix III - Sealing Fixture

